

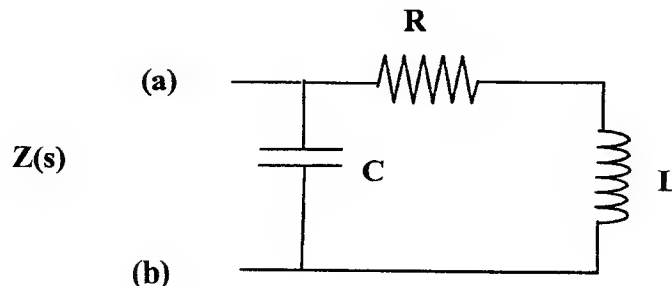
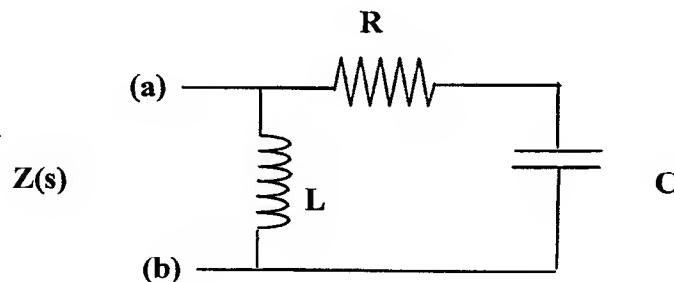
EP311 Fall Term 2005
Final Exam (50% of total course grade)

6 problems, all equal weight

Problem 1: Generalized Impedances

Write the generalized impedances $Z(s)$ presented between the terminals (a) and (b) of the 2 circuits shown below. Arrange the expression for $Z(s)$ such that you have polynomials in increasing powers of s in both the numerator and denominator.

Sketch on the s-plane the poles and zeros in each case. Note that you may assume that component values have been chosen such that $\left(\frac{R}{2L}\right)^2 < \frac{1}{LC}$



Problem 2: Semiconductor Physics

The portion of the periodic table most important for semiconductor work is reproduced below

Group III	Group IV	Group V
Boron (B) Z=5	Carbon (C) Z=6	Nitrogen (N) Z=7
Aluminum (Al) Z=13	Silicon (Si) Z=14	Phosphorus (P) Z=15
Gallium (Ga) Z=31	Germanium (Ge) Z=32	Arsenic (As) Z=33
Indium (In) Z=49	Tin (Sn) Z=50	Antimony (Sb) Z=51

- A silicon sample is doped with Boron such that $N(B)/N(Si) = 10^{-6}$. What type of doping is this? What is the electrical conductivity?
- The same sample is now doped with Arsenic to the ~~same concentration~~, i.e. $N(As)/N(Si) = 5 \times 10^{-7}$. What type of doping does this produce? What is the conductivity now?
- Compare the conductivities of the two doped samples. Which is higher, and why?

Additional Useful Information

Physical Parameters for Silicon:

Atomic concentration

$$N(Si) = 5.0 \times 10^{22} \text{ cm}^{-3}$$

$$n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$$

$$\mu_e = 1350 \text{ cm}^2/\text{V.s}$$

$$\mu_h = 480 \text{ cm}^2/\text{V.s}$$

Recall also $\sigma = e(n_e \mu_e + n_h \mu_h)$ { e = electron charge = 1.6×10^{-19} Coulomb}

- At room temperature (assume 25 degrees C) the current in a silicon diode is measured to be 200 mA at a forward bias voltage of 0.7 Volt. What is the reverse leakage current for this diode? What current would flow at a forward bias of 0.6 Volt?

Ref: Shockley equation $I = I_0 [e^{(eV/\eta kT)} - 1]$ ($\eta \approx 1$ and $k = 1.38 \times 10^{-23}$ J/K)

Problem 3: Bipolar Junction Transistor (BJT)

(a) In the circuit given below the Bipolar Junction Transistor Q1 has the following parameters at room temperature (assume 25 °C):

$$\beta = 100$$

$$I_{CBO} = 100 \text{ pA.}$$

Given the following changes in parameters as a function of temperature:

$$\Delta V_{BE} = -2.5 \text{ mV/}^\circ\text{C}$$

I_{CBO} doubles for every 10 °C rise in temperature

β increases from 100 to 200 when the temperature increases by 50 °C

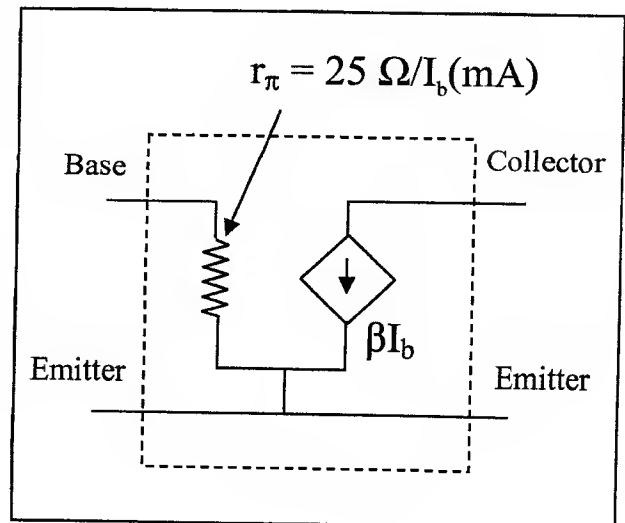
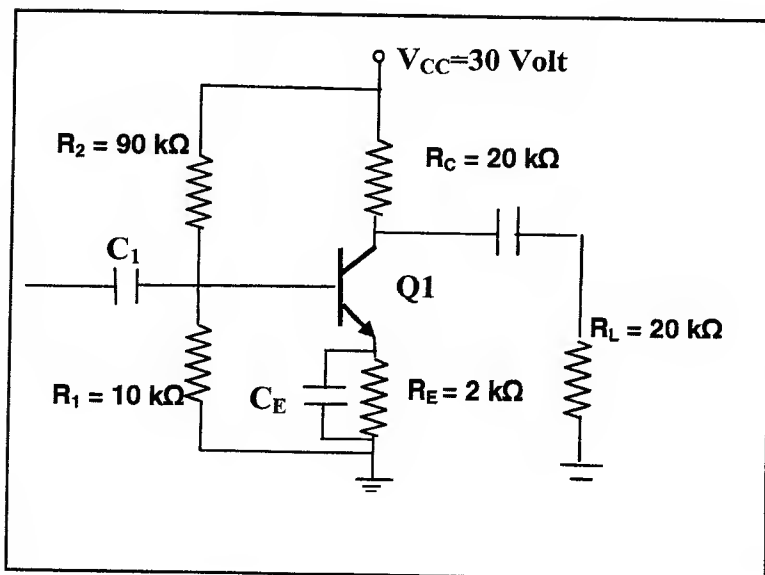
Use the standard BJT bias stability equation (given) to calculate the change in collector current due to a

$$50^\circ\text{C rise in temperature: } I_C = \frac{V_{BB} - V_{BE} + (1 + \frac{1}{\beta})I_{CBO}(R_B + R_E)}{R_E + \frac{R_B + R_E}{\beta}}$$

(Recall that R_B is the parallel combination of the base bias resistors R_1 and R_2 , i.e. $R_B = R_1 // R_2$)

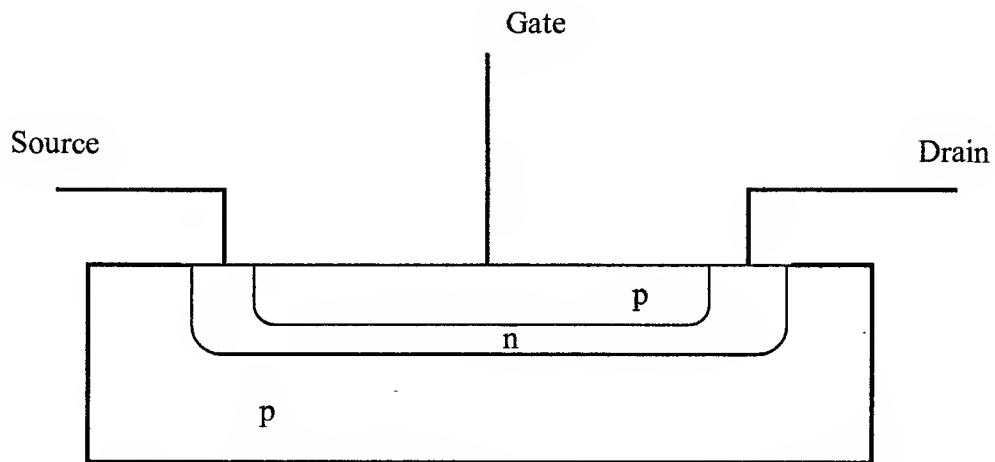
(b) If the lowest desired frequency of operation is 2 kHz, choose capacitors C_1 , C_2 , and C_E

(c) Draw the AC equivalent circuit assuming the capacitors have been chosen correctly and that V_{CC} is an AC ground. Then replace the transistor by the $r_\pi - \beta$ model of the transistor shown in the figure and calculate the voltage gain (Remember the emitter is AC-shortcd to ground if the C_E capacitor is properly chosen)



Problem 4: JFET Circuit

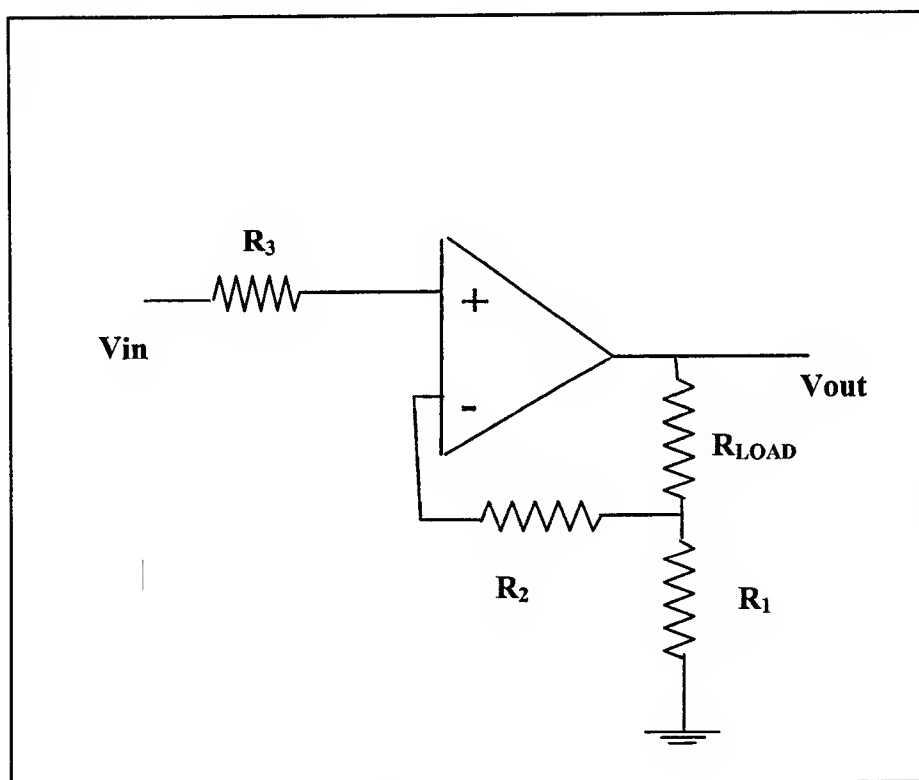
- (a) Explain qualitatively how the following n-channel JFET works. Sketch a circuit showing the proper biasing for this device
- (b) What is the circuit symbol for this device, and why is it drawn the way it is ?
- (c) Why do we never forward bias the gate channel junction ?
- (d) What is the chief advantage of a JFET over a BJT ?



Problem 5: Op-amp DC Current Source

Use the op-amp current and voltage rules (OACR and OAVR) to find the expression for the current through the load resistor R_{LOAD} in terms of the input voltage V_{in} for the circuit below.

Describe the function of this op-amp circuit in words.



Problem 6: Op-amp AC Circuit – Effective Inductance using Capacitors & Feedback

- (a) Derive the relationship between $V_{in}(\omega)$ and $I_{in}(\omega)$ for the following op-amp circuit by using the op-amp current and voltage rules (OACR, OAVR).
- (b) What is the effective inductance of this circuit ?
- (c) Why is this not a true inductor simulator ?

